By Signal Indication

I

The Two Principal Methods of
Directing Train Movements

II

Directing Train Movements
by Signal Indication

Bulletin No. 3

56

Train Operation by Signal Indication

"Signals keep trains moving"

Train Operation by Signal Indication

I

The Two Principal Methods of
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Directing Train Movements
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By

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M. AM. SOC. C. E.

1920

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PART I

PART II

A Call for More Efficient Signaling

Editorial from RAILWAY AGE, June 18, 1920

THE STUDY of train operation, by H. M. Sperry, printed in the *Railway Age* of June 4 and June 11, brings together numerous scattered facts and arguments concerning train despatching and signaling, with which most of us are already familiar but which we sometimes neglect because, apparently, of the very fact that they are familiar. He includes numerous things which we already know, but do not know well enough. He proposes what seems like a radical change—to abandon all written orders and convey instructions to enginemen wholly by means of signal arms supported on roadside posts. And yet the proposal is not radical, for the practice proposed is already in use, and familiar to everybody, in large interlockings, at dozens of cities; and the only change in fundamentals that is here suggested is to extend this practice; to extend a limit of two miles, to one of two hundred miles. Or, to take another comparison, the proposal is that the perfect facility with which trains are moved under automatic block signals on a double-track road, with blocks less than a mile in length, ought to be availed of in varied situations where
we have all along assumed
facility was impracticable or t
And it is only because of a la
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has not been already acco
We are called upon to more
take account of our resources

The problem outlined by M
ought to be divided into two
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to divisions or parts of divisi
block sections must be short a
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are needed. If any one think
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thus picking out the points b
one or the other of these two
Another suggestion, to any
thinks it a burden to read n
one page at a sitting, is that M
has on several occasions prin
of the salient points of his arg
the outside back cover of the
Age. The editor has no
against the advertising pages

Mr. Sperry puts his claim f
ing in the form of a plea for

formal or definite recognition of signaling as a cardinal element in operating efficiency. Near the end of his article he says:

Operating Efficiency

The efforts that have been made to increase operating efficiency have largely been in the direction of:

1 Increasing the tractive power of the locomotive.

2 Increasing car capacity.

3 Increasing track facilities by the addition of second, third and fourth main tracks, longer passing sidings and larger yards and terminals.

4 By the electrification of steam-operated roads.

These improvements, which require large expenditures, may fail to show an adequate return if the means for directing train operation does not keep trains moving.

In other words, a fifth head should be added to these four. Progress in the four features has been made along well-known and unmistakable paths, apparent to all. This progress has been reasonably steady (until the abnormal times of the past three years) because competent judges have been fairly unanimous in their views as to what was needed and how the needs should be met. But is there not an equally intelligent unanimity as to the value of those features of signaling which are emphasized by Mr. Sperry? In other words, is there any reason for disagreeing with him on any important point?

The American despatching system has done great things, and has a fascinating history; but if there could be taken a composite motion-picture of the freight-train movements of a day in, say, the whole "Eastern Region," *showing clearly the percentage of trains standing motionless on the main track* (or on sidings awaiting right to the main track) because of the lack of adequate fixed signals, the force of this argument for an advance in efficiency would be overwhelming.

Train Operation by Signal Indicat:

Part I

The two principal Methods of directing Train Movements

ON the railroads of the United States two principal methods of directing train operation are in use:

a The Time Interval Method, and
b The Space Interval Method.

The first part of this article will describe briefly these two principal methods, and a comparison of the two methods will be made. This comparison will show that, due to inherent disadvantages, the time interval method is not efficient for directing train movements. On the other han(vantages of the space interval n such that it is *the* method that] efficient train operation.

The increasing costs of lab(fuel emphasize more than ever for the greatest possible efficien(operation.

The second part of the a) describe train operation by sign tion and point out the marked adv this method of directing train m(

Time Interval Method

Train operation under the time interval method is directed by:

1 Time tables
2 Train orders
3 Train order signals
4 Train despatching

The time table is the primary authority for the movement of regular trains. Train orders are the authority for movements not provided for by time tables, and for regular time-table trains when, because of delays, the time table must be modified or temporarily suspended. The movement of trains according to time tables and rules which specify a minimum number of mi tween trains moving in the same is the distinctive feature of the t val method. For trains not car sengers this interval is usually fiv(for trains carrying passengers minutes.

1 Time Tables

As defined by the American Raili ciation's Standard Code, the tin "The authority for the movemen lar trains, subject to the rules. I classified schedules for trains, wi instructions relating thereto."

* This study of train operation was first published in the *Railway Age* of June 4 and June 11, 1920

thority for the movement of an extra train on single track is a written order from the train despatcher, customarily sent by telegraph or telephone; in common parlance, "train orders." On a double track line extra trains may be run without formal train orders. In this case the only serious complication is the necessity for keeping slow trains out of the way of those which run faster, and this is usually provided for by a general rule that extras thus run without formal order shall clear the main track ten minutes before the time at which a following faster train is due, by the time table, to arrive. If the extra is a fast train it is *not* run without a despatcher's order.

Prior to the use of the telegraph in train operation, the time table was the sole authority for train movements. Had it been possible to run all trains in exact accordance with the time table, operation of trains would have been a comparatively simple matter. It was not possible, even in the early days, when every road had light traffic, to avoid serious delays to trains; and, without electrical communication, the art of railroad operation would have been dwarfed in its infancy. The use of the telegraph for authorizing movements, not provided for by the time table, first made it possible to transport passengers and freight without intolerable delays.

2 Train Orders

The train order, therefore, came into use to supplement the time table. It is defined by the Standard Code as follows: "For movements not provided for in the time table, train orders will be issued by authority and over the signature of the superintendent. They must contain neither information nor instructions not essential to such movements. They must be brief and clear; in the prescribed forms when applicable; and without erasure, alteration or interlineation. Figures in train orders must not be surrounded by brackets, circles or other characters."

The Standard Code embodies explicit rules and contains forms designed to insure uniformity of practice in the preparation, transmission, and delivery of train orders.

Train order forms may be grouped into three general classes:

a *For directing train movements* the orders in use are: the meet, the pass, the right, the time, and the hold, orders.

b *For designating the kind of trains* to be run: the section, the extra, or the work-extra, orders are used.

c *For modifying orders:* the annulling or the superseding orders are used.

It will be noted that the principal class is that for directing train movements (*a*).

3 Train Order Signals

The usual type of station train order signal is the two-arm semaphore signal, one arm for movements in one direction and the other for movements in the opposite direction; each arm capable of being displayed in either one of two positions; one position indicating "stop" to approaching trains and requiring them to stop for train orders to be delivered to them; the other position indicating "proceed," to be displayed when there are no orders to be delivered to trains moving in the direction to which that arm applies.

4 Train Despatching

Train despatching may be defined as the art of directing train movements. It is to the credit of the American train despatcher that he has been able so skillfully to meet the constantly increasing requirements of transportation.[1]

[1] See Appendix at end of article, for the principles of Train Despatching, from book on "Telegraph as Applied to Train Movements," by J. J. Turner, Vice-President of the Pennsylvania system.

Directing Train Movements

The directing of train movements is accomplished through the use of general rules, local rules, time tables, train orders and train order signals. Under the space interval method there is, in addition, the use of block and interlocking signals.

Directing train movements may be considered broadly under two general heads—

a The preparation and transmission

b The delivery of instructions, rules, time tables and train orders

This division under two heads is to show the marked difference between the preparation and delivery of instructions, rules and time tables on the one hand, and the preparation and delivery of train orders on the other. In the first class we have what may be termed permanent elements, whereas train orders are of a temporary nature.

Instructions, rules and time tables are the *plans* for conducting train operation. They must be prepared and delivered in advance of the time of their use. Train orders, on the contrary, are to meet the ever changing needs which cannot be provided for in advance and must be often made on the spur of the moment. If train operation could be conducted by time tables without delay it would not be necessary to use train orders; such mathematical precision being impossible, train orders and train despatching are essential in efficient train operation. As stated, train orders differ from instructions, rules, and time tables as to the time available for their preparation and delivery. There is ample time for handling instructions, rules, and time tables; but train orders must often be formulated and transmitted with the utmost speed. The despatching is not efficient if the handling of the train orders causes delay. This may be true even if the order reduces a prospective loss of time, as where the delay would have been still further reduced had there been no del
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in requiring him to go to the stati
it is provided that his copy ma
livered to him by the conductor).

The Form 19 train order is requi
signed for only by the station opera
is held personally responsible for t
ery of the "19" order, but the form
require the signature of the cond
the engineman or any other ack
ment by signature to the despatch

Because of this difference in del
moving train is required to stop fo
order, but need only slacken spe
"19" order. If the order should a
the train to continue its journey,
delivery of the "31" order, requi
train to stop, causes a useless de
might have been avoided by the u
"19" order. The disadvantages c
with the stopping of trains simply
them instructions under which t
proceed will be more fully consider
the Space Interval Method.

William Nichols in his excellent
"Train Operation" says: "The us
'19' form is not restricted by the S
Code. However, some roads pro
use for restricting the superiority o
There has been and still is, no dou
siderable prejudice against the '

order. This is generally because of not thoroughly understanding the difference between the '31' and '19' forms so far as safety is concerned. With a proper clearance card made for the purpose, and with a few restrictions placed upon its use, it is as safe [as the '31'] and certainly is far the best order for the prompt movement of trains."

John F. Mackie, formerly secretary-editor, Train Despatchers' Association of America, and a veteran railroad operating officer, in his article on "Train Rules and Train Despatching Past and Present" declares the crux of the whole matter to be the delivery of the order. "There is increased assurance of delivery of the '19' form because of the requirements that the operator shall personally deliver the order to both the engineman and conductor. He is, therefore, out on the platform prepared to make the delivery. * * * He is an active, instead of a passive agent, in the delivery of the order."[2]

Space Interval Method

Train operation under the space interval method is directed by:

1 Time tables
2 Train orders
3 Train order signals
4 Train despatching
5 The block system

Trains are operated under the space interval method by time table, train orders, and train despatching, the same as in the time interval method. In addition, there are block signals. Although trains are moved under time tables, the block signals enforce an interval of space between trains moving in the same direction, wholly regardless of the time interval. This is the distinctive feature of the space interval method, and is the basis of the block system. The time interval is maintained by attendants, with watches or clocks, at stations. Suppose, under this system, the prescribed interval be ten minutes. At the expiration of that length of time after the departure of the last preceding train, the attendant displays to a train a proceed signal; but if the preceding train has been unexpectedly stopped at some obscure point between this and the next station, this proceed signal is deceptive; it does not remove the danger of a collision under such circumstances, and this danger has to be provided against by the flagging rules. But if the space interval system is in effect the station agent, instead of allowing a train to proceed at the end of a period of 10 minutes holds it until he has been informed that the preceding train has actually arrived at the next station, whether the time be 10 minutes or 10 hours. Thus the time interval, in such a situation, is superseded, so far as concerns its function as a preventive of collisions. It becomes merely a convenience.

1 Time Tables

Under the time interval method, in order to comply with the five and ten minute rule, trains must not be scheduled at intervals less than five [or ten] minutes. In the space interval method, however, trains may be scheduled at intervals determined by the time required for them to move through the block sections. The passenger service on the express tracks of the Interborough subway, New York City, is a notable example of moving trains under close intervals. There, under the automatic block system, with sections less than 900 feet long, ten-car passenger trains, moving at 35 to 40 miles an hour, are al-

[2] Proceedings Central Railway Club, September, 1916.

lowed to follow one another at intervals of one minute and 48 seconds. Without the block system, the time interval system, dependent for safety on the flagman, would be out of the question. Before a flagman could get off his train to start back with his stop signals the time interval would be used up.

2 Train Orders

In the space interval method there is a decrease in the number of train orders issued, and of those which are issued a larger number are on Form 19, as compared with Form 31. The decreased use of the written train order is fully considered under Train Operation by Signal Indication. The "19" order keeps trains moving, and obviates one of the most undesirable features of train operation, as heretofore extensively practiced, the stopping of trains for the sole purpose of giving them written train orders.

Eliminating the unnecessary stopping of trains, saves fuel and water and the cost of the wear and tear on cars and engines for these useless stops. Every unnecessary stop creates an unnecessary hazard. By eliminating unnecessary stops, unnecessary hazards are eliminated. Every unnecessary stop is an unnecessary delay, not only to the train that is required to stop, but often to other trains as well.[3]

3 Train Order Signals

The two-position train order signal, heretofore referred to, *has but a limited use in directing train movements*. It is used only to indicate "stop" for orders; or "proceed" when there are no orders. There is an increasing demand for a signal that can be used in place of, not merely as an adjunct to, written train orders.

A signal is needed to direct trains t

a "Take siding,"

b "Hold main," or proceed on ma regardless of superior trains.

On double-track roads equipp block and interlocking signals, trai ments at the interlocking stations rected by the interlocking signals.

At non-interlocked passing-sidin is a need for a signal to indicate "t ing," or "hold main." The Erie] (one of the first to meet this need) this purpose a three-position se train order signal giving three ind "proceed," "take siding," and "sto

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Estimated Monthly Saving b Use of the "19" Order

The St. Louis & San Francisco] has made an estimate of the e effected by the elimination of usel by the use of the "19," instead of t order, and reports an annual savin average of 27½ trains per day, of as follows:

Reduction of overtime, 5 hours a day, at $4.18 an hour......	
Saving one-half ton coal per freight train per trip, at $3.25 a ton....................	
Saving in wear and tear in not stopping "long-drags" for orders, $10 a day............	
Saving per month...	**$2**

Or an annual saving of $29,630; equal to interest at five per cent o vestment of $592,596.

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[3] "See Increased Efficiency by Use of Train-Orders Form Nineteen," by T. H. Meeks, *Railway Age*, February 1, 1918.

[4] See "Train Operation by Signal Indication Railroad," *Railway Age*, July 5, 1918, page 5.

4 Train Despatching

The principal purpose of train despatching as already suggested in the discussion of the time interval system is to so direct the operations of trains that they may move with maximum safety and minimum delay. Train despatching has reached a higher level of efficiency under the space interval method than was possible under the time interval method. This has been accomplished by the use of:

a The automatic block system

b The "19" train order

c Signal indications in place of written train orders

The train despatcher directs the movement of trains as if his division were a great, interlocking plant. He sends his instructions or orders to the signalmen at the block and interlocking stations; these signalmen in turn direct the movement of trains by signal indications. It is thus possible to move maximum traffic with a minimum delay. The *written* order, with its delays and opportunities for error, is replaced by the fixed signal with its instantaneous operation and unmistakable indications. A despatcher can order a signal cleared, can get it cleared and receive the station operators' assurance that the object is accomplished in less than one minute; whereas, a train order would require several minutes for transmission and transcription, to say nothing of the delay to the train and the time required by the trainmen for reading it.

5 The Block System

The Interstate Commerce Commission defined the block system at length in its seventeenth annual report (December, 1903). The following is quoted from this report:

"The term 'block system' shall be taken to mean the methods and rules by means of which the movement of railroad trains (cars or engines) may be regulated in such a manner that an interval of space of absolute length, may be at all times maintained between the rear end of a train and the forward end of train next following."[5]

The Block Signal and Train Control Board defined the block system as:

"Any method of maintaining an interval of space between trains moving on a railroad. Primarily the term refers to the spacing of trains moving on the same track in the same direction, but in practice it is used, on single track lines, both for this purpose and for the protection from each other of trains moving in opposite directions toward each other."[6]

This last definition is a clear statement of the object of the block system, which is to maintain "*an interval of space between trains moving on a railroad.*"

The Standard Code gives definitions, requisites, and rules for the three block systems; the manual, the controlled manual, and the automatic. The manual block system is "a series of consecutive blocks, governed by block signals operated manually, upon information by telegraph, telephone or other means of communication." The controlled manual is "a series of consecutive blocks governed by block signals controlled by continuous track circuits, operated manually upon information by telegraph, telephone or other means of communication, and so constructed as to require the co-operation of the signalmen at both ends of the block to display a clear or a permissive block signal." The automatic is "a series of consecutive blocks governed by block signals operated by electric, pneumatic, or other agency actuated by a train, or by certain conditions affecting the use of a block."

[5] Seventeenth Annual Report, 1903, p. 345, Sec. 14.

[6] Interstate Commerce Commission; First Annual Report of the Block Signal and Train Control Board, 1908, p. 71.

Time Interval vs. Space Interval

Comparison of the Two Methods

The character of the interval between trains moving in the same direction is the principal difference between these two methods.

In the time interval method, the interval between trains is maintained at stations usually situated at varying distances apart. This time interval, on most railroads, for trains not carrying passengers, is five minutes; for trains carrying passengers it is ten minutes. This time interval, as provided by rule, is to allow time for a flagman to protect the rear of a standing train by red flag or red light; and also by torpedoes and fusees. In the space interval method the interval between trains, whatever their class or character, is a *space* interval for all trains. Fixed signals provide for this space interval. The space intervals are called blocks.

Operating Efficiency of the Two Methods

As has been shown, it is necessary with the time interval method to allow a larger time margin between train movements than is required with the space interval method. On account of this larger time margin, the time interval method is correspondingly less efficient than the space interval.

Both delays and hazards are reduced to the minimum in the space interval method, and its superior efficiency is obvious. Operation at maximum track capacity is not possible under the time interval method. Operation at maximum track capacity under the space interval method *is* possible.

Relative Safety Factor of the Two Methods

In the time interval method two types of fixed signals are used—train order signals and interlocking signals; these sig being used to space trains.

The protection of trains depen the rules requiring trains to keep number of minutes apart, and u flagman's signals for the prote standing or slow-moving trains.

The Interstate Commerce Cor in a report to Congress, describing tations of the time interval meth

"Without the block system, the a train to proceed depends:

a On the class of the train as rega trains

b On the time, as shown in the ti

c On the vigilance of the engin seeing that the preceding train his way

"Under the block system these o vital features become matters m convenience or expediency. With system rear collisions are providec by flag or lantern signal, but the f this safeguard is notorious. It fa from the negligence of flagmen to c or display the signal, and of engir heed it when it is given. On a sin line, in addition to these uncertair men in charge of trains have the b considering their rights as again coming from the opposite directio are of two or more different clas the superiority of which, as relatec train, may vary from hour to hour be varied by telegraphic orders train despatcher at any stage of th journey. Butting collisions, due sion in these things—to mistakes i the time table, to wrong telegraph to non-delivery of orders, to f orders, and other blunders—are as as are rear collisions from flagmen's

"On either double track or single track we have on the one hand (in the block system) fixed signals, situated at known locations, few and simple requirements, and few men to share the responsibility of any given operation. On the other hand, we have in the old system, signals (as flags) not fixed but to be encountered at unexpected places, or no signals at all, compelling dependence on the time tables, watches, and confusing rules of superiority. Responsibility is divided among a larger number of men."[7]

In the space interval (block system) method three classes of signals are used—

1 Train order signals
2 Interlocking signals
3 Block signals

The first two have the same functions as under the time interval system; but the interlocking signals (where they are part of a block system) are used also for spacing trains. The block system, of course, is not absolute perfection, and every road keeps in force the rule requiring flagmen to protect standing or slow-moving trains by hand signals (flags, lanterns, torpedoes and fusees).

"The block system provides that each engineman may, with perfect safety, start and run his train by the sole authority of a visible signal, fixed on a post at the side of the road, which gives him the exclusive right to the track for a given distance (to the next block signal) without limitation as to the time to be spent in getting there, or the speed. The system provides all necessary security against collision, with no question about the importance of the train, or the priority of any other train. So far as safety is concerned, all trains are of the same class."[8]

[7]Report of the Interstate Commerce Commission on Block Signal Systems; Senate Document No. 342. 1907; p. 11.

[8]Senate Document No. 342, p. 11.

To maintain between trains a safe and satisfactory interval of *space*—in other words, to prevent collisions—and to do it wholly by means of time—by the use of clocks and watches—would require a station with a clock (and an attendant) every few hundred feet, and it would be imperfect even then, for the theory of the time interval system requires a length of time sufficient for a flagman to go back and flag. Hence, the inherent weakness of the system. A complete system should have stations, say 1,000 feet apart, and it should have flagmen capable of always going back 1,000 feet, in, say, two minutes. A mere glance at a situation like this makes evident the weakness of the system.

Automatic clocks have been tried, but they only serve to show in stronger light the fundamental insufficiency of any time-interval system. A clock on a 20-foot post at the side of the road was in use for a short time on the Fall Brook Coal Company's railroad in central New York some 25 or 30 years ago. Being set at zero by every passing train it would show to the next train how many minutes had elapsed since the passage of the car wheels which acted to start the hands from zero. But on a crooked road, or on any road in time of dense fog, it would be necessary, in order to give the enginemen the necessary confidence, to locate the clocks very close together. This might answer for slow trains—provided the clocks were well cared for and reliable, and provided discipline of enginemen was very good, but for fast trains the short space interval would be a hindrance without two or more distant (cautionary) signals; for a fast train must have a long stretch of track in which to reduce its speed after receiving warning of the train ahead, and with suitable distant signals the space interval with its superior simplicity would be as feasible as the clock interval. And all this ignores one of the important virtues of the automatic block system—its function of detecting broken rails and open switches.

Relative Safety of the Three Block Systems

1 The Manual Block System

a A man-operated system

b The signals are operated *entirely* on information transmitted by telegraph, telephone or electric bell code

c The correct operation of the system is entirely dependent *upon human agency without mechanical check*

2 The Controlled Manual

a A man-operated system

b The signals are operated on information transmitted by telegraph, telephone or bell code

c The correct operation of the system is dependent *upon human agency, checked by track circuits* throughout the length of the block section

3 The Automatic Block System

a A power-operated system

b The signals are operated by "electric, pneumatic or other agency"

c The operation of the instruments in the system is controlled, not by human agency but by the passage of the train into and through the block section, through the medium of the continuous track circuits

From a safety standpoint, the control of the signals by the train is the vital point of difference between the systems. In the manual block system the *train does not control the operation of the signals,* for no mechanical check is provided, when the block is occupied by a train, to prevent the display of a clear signal behind it. In the controlled manual system the train but partly controls the signals. In the automatic block system the *train completely controls them.*

Relative Operating Effici of the Three System

Delays of trains reduce the capacit tracks; therefore, the operating e of the three block systems may l sured by the relative amount of t lays directly chargeable to block op

Train delays chargeable to blocl tion are unavoidable if the block are too long for the movement of t frequently as the terminal is ready them out.

The ideal method for determin length of block sections to insure o efficiency is by taking the requir interval between trains—the frequ quired by the volume of traffic wh desired to move—and making t lengths of the block sections such permit of train movements und signals. Measured in time the block will be the same, but measured in the block lengths will vary with th *e. g.*, the short block on an up grade the equivalent of a much longer bl down grade. Or, further, the b which a station or other stop is ma be shorter in length than one in w stop is made.[9]

In the two manual block syste ideal method is often disregarded of the tendency, when locating bl tions, to give first consideration to of wages of signalmen. This consi for wage cost is at present a const turbing element because of the eig law requirement of three signalmen block station. When the wage made the first consideration, an stations are placed at passenger st utilize the men at these stations operators, the result is often a blocks that vary so greatly in leng as to distance and time, that t

[9] See Report of Committee X—Signaling Pra nal of the Railway Signal Association, March 1

of trains is limited by the *longest* block. Long intervals between trains are thus inevitable.

In the automatic block system the ideal method can be followed, as the wage cost for block operators need not be considered. The block section lengths and the location of the signals can be arranged for moving trains at maximum track capacity.

The following is an interesting comparison of a manual block system installed on a double-track division of 139.5 miles that was later changed to an automatic block system with a marked improvement in operating efficiency:

Under the manual block system there were 46 block stations and 90 blocks. The average length of blocks was 3.1 miles, but with great differences in their lengths. The shortest block was .39 miles in length and the longest 7.27 miles; 58 blocks ranging from .39 to 4 miles; 16 blocks from 4 to 5 miles; 12 blocks from 5 to 6 miles; 2 blocks 6.89 miles, and 2 blocks 7.27 miles in length.

Under the automatic block, since introduced, there are 296 blocks of an average length of .94 of a mile.[10]

The elimination of delays chargeable to operation under the manual block was one hour and forty minutes per freight train, or a saving in time per train of 15 per cent.

By the improved operating efficiency the saving of expense in train operation was enough to pay for the automatic block *in less than four years.*

[10] Erie Railroad, Susquehanna Division.

Conclusions

In a final analysis of the three block systems to determine which is the most efficient from an operating standpoint, it is necessary to place them on an *equal basis as to track capacity.* Assuming block sections one mile in length, the manual block is the lowest in first cost. The controlled manual is the highest in first cost (installation); but both systems are so high in cost of operation that it is the exception to find either the manual or the controlled manual with the number of block sections necessary for maximum track capacity.

On the contrary, the first cost of the automatic block (somewhat less than the first cost of the controlled manual) is the lowest of the three systems in cost of operation.

The automatic block shows the greatest operating efficiency per dollar of investment.

Part II

Directing Train Movements by Signal Indic

Train Orders vs. Signal Indication

Single Track Operation without Written Train Orders

THE first part of this article contains a condensed description of our two principal methods of directing train operation:

a The time interval method (clocks, time tables and train orders, with the flagman as a necessary adjunct) and

b The space interval method or block system (an absolute interval of space between trains); this as a preliminary to the study of the problem of train operation by signal indication.

On double-track roads this problem was never a serious one, except as it has been complicated by attempts to operate the system with incomplete facilities, as, for example, allowing second-class trains to clear superior trains at sidings midway between block stations. On single-track roads progress in the solution of the problem has been slow.

This second part will describe in some detail the actual work of the train despatcher under the two methods.

Under the first and time-honored method the train despatcher's whole day, so far as it manifests itself outwardly, is devoted to the preparation of written orders, getting them delivered to conductors and enginemen and making for himself a sat record that each act has been cc infallibly.

Under the second method of dire signal indication, the despatcher is of his chief burden, that of avoidin errors which produce great horro the whole business of train ope *simplified*, *accelerated* and mad These commonplace terms are so that we become careless of thei cance, but each one of them sig itself, an element of importance busy railroad; for the despatcher's the nerve center of the whole mon ing machine, and its smooth an structed action should never be as of minor importance. That i function perfectly at all times i portant in its field as that the manager's brain should always be every act and every neglect of h subordinate officers. The des work should be *simplified* in every detail and to the last degree, so as t internal friction—to borrow a me term. Everything possible should to enable him to make every mov least possible *time*, because losses utes at his desk may and often do losses of dollars out on the road. The prime duty of making train movement *safer* goes without saying. This essay is addressed mainly to the question of economy; but, fortunately, the pursuit of economical financial results and of greater security to the lives and limbs of passengers and employees can be treated as a single pursuit. There is no incompatibility and there should be no division of purpose.

Train Orders vs. Signal Indication

Train orders are written instructions that must be delivered to the conductor and engineman of the train. They must be correctly prepared, transmitted, delivered and understood. *They must not be forgotten.* On railroads *not* equipped with controlled manual or automatic block systems, safety of operation depends entirely upon the human element, for there is no check, either electrical or mechanical, to prevent an improper train movement should an error occur in the preparation of the order or should the order be misunderstood or forgotten.

Signal indications are instructions given by the aspects of fixed roadside signals. The subject is here dealt with as it relates to railroads equipped with the controlled manual or the automatic block signal system. Instructions given by signal indications require less effort in preparation and transmittal than do written instructions. *They are delivered to the engineman through the medium of the signal.* The language of the signal is easy to understand and difficult to forget.

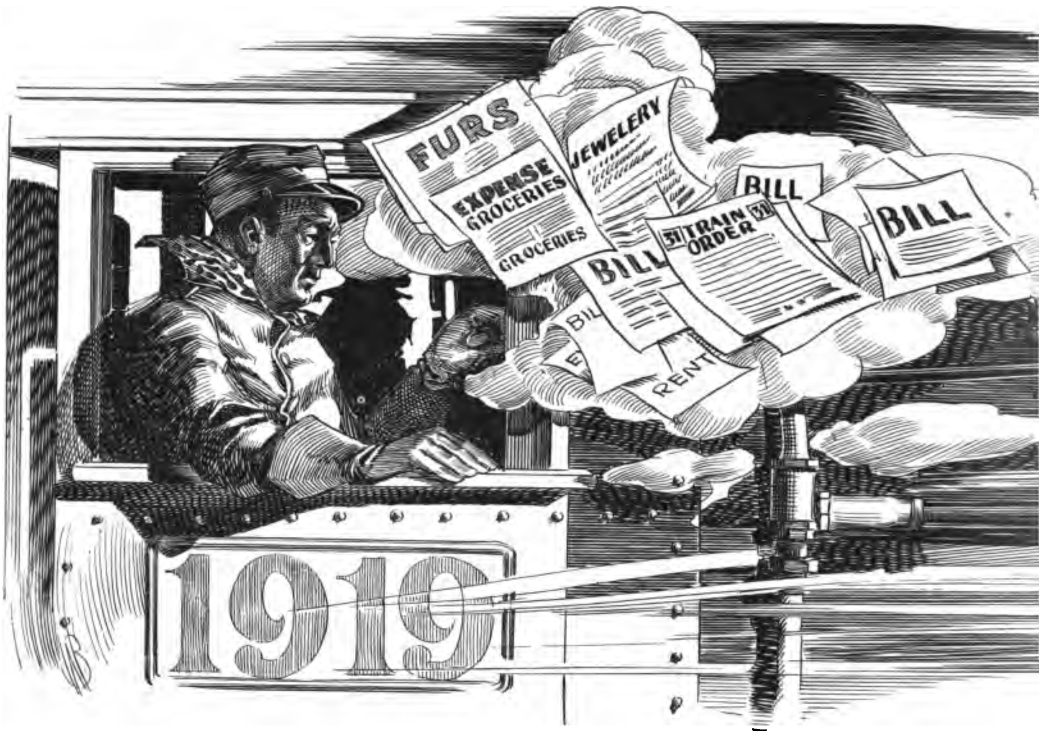
Because the aspects are few in number, there is little opportunity for misunderstanding. Of more importance, the instructions conveyed by the signal are given at the point where they are to be executed, and no lapse of time in which to forget them is possible.

Safety of operation under signal indications does not depend entirely upon the human element as in the time interval method.

Comparison of the Two Methods

Psychologists tell us that the strength of a mental impression is strongest at the time it is received and grows weaker with the lapse of time. In the train order method, especially with the more important class of orders, the necessary lapse of time between the receipt and the execution of the order is an element of weakness.

For example, take a train order of Form A, reading: "No. 1 meet No. 2 at B." This order, as is often the case, may be for execution at a siding many miles distant. At the time that the train is to execute the order the engineman's mental impression of the order should be strong and clear. Because of the lapse of time—perhaps an hour or more—and the multitude of subsequent impressions, the train order impression is too often weak and blurred. This point has been well brought out in a recent article by George Bradshaw, supervisor of safety of the Pere Marquette Railroad, in which he exhorts enginemen to take care not to confuse their mental impression of an important train order with other impressions not relating to it. He presents a picture which is a striking illustration of what may flash through the mind of an engineman during the lapse of time incident to the train order method.



Bad Company for a Train Order

The train order calls for deferred action; the signal indication calls for immediate action. The movement required by a train order is seldom made upon receipt of the order. The signal indication is a "do-it-now" order.

Train operation by the train order method requires the delivery of the order to the train. If the train is in motion it must slacken speed or stop to receive the train order. The signal indication method, on the contrary, does not require the train either to slacken speed or to stop.

The train order method, when it thus retards the movement of trains, causes loss of time to cars, engines and men. Furthermore, it unnecessarily obstructs the particular sections of track occupied by the delayed trains, and it requires the consumption of additional fuel to regain the normal speed. The train order method therefore reduces the railroad's output of transportation, and increases train costs. To produce and sell transportation a railroad must keep its trains moving; hence any method that unnecessarily ret stops the movement of trains te destroy production.

American Railway Associa Rules for Train Operati by Signal Indication

Without the block system the trai method, as usually operated, is a both of safety and convenience (cc ence with important drawbacks, wh customarily regarded as necessary As soon as regular trains are much time they must be moved regardless time table. This necessitates the despatchers' orders to keep the trai of each other's way—to give the right to the road. This is a safety fu But with block signals the trains, w dependence on the despatcher, ar vented from running into one anothe despatcher's function is not so distin an element of safety, but his orde tinue to be necessary as a convenience, for as long as passenger trains are superior to freight trains, delayed passenger trains will cause delays to freight trains, and delayed freights will delay still other freights. It is the despatcher who must reduce or prevent these delays. If trains were all of the same class, and the absolute block system were universal, there would be no need of the despatcher for safety and very little need for convenience.

When we speak of train operation by signal indication we mean the use of fixed roadside signals not only as:

1 The means of preventing a train from colliding with the preceding train or as
2 A means of indicating to a train which of two or more diverging routes it shall take, but also, in addition to either or both of these, as a means
3 Of indicating, at the will of the despatcher, under certain circumstances, whether or not a train shall actually make every move which the signals, if not controlled by the despatcher, would permit it to make.

For example, an automatic block signal indicates to an approaching freight train that it may proceed from B to C. The road is clear. But the despatcher desires to have the train enter a side track half way between B and C for the purpose of allowing a passenger train to pass and run ahead of the freight. To carry out his purpose he causes the automatic block signal to give a modified indication. He uses the signal where under former methods he would use the time-consuming process of a written order conveyed by wire to a station operator.

Train operation by signal indication is not new. As early as 1903 the subject was under consideration by a committee of the American Railway Association. The problem at that time was stated as follows:

"The term 'operation without train orders' is, of course, something of a misnomer. The system contemplates rather a change in the manner of delivering orders, the method of working under them and the relief of the engine and train crews from the frequent necessity of performing more or less complicated arithmetical problems in order to determine exactly what their orders are. With a train scheduled at a certain time for every station on a division and with an order requiring it to run one hour and 30 minutes late from a certain point, the possibilities of error in the calculation of time are large. The fact also that freight trains are required to keep out of the way of trains of a superior class running in the same direction involves either undesirable delays in waiting at passing stations or the taking of long chances in getting to the next passing point. . . .

"The plan in brief is, on double track, to allow all trains to proceed under a block signal showing clear, without regard to any train of superior class that may be following. The rule on the time table covering this point is: 'The right of any train to proceed will be indicated by the position of the train order or block signal. A clear signal will give to any train for which it is displayed the right to proceed in advance of first-class trains without train orders.' The control of the train is thus vested in the despatcher. The conductor, while he is not relieved of responsibility and is required to keep himself informed as to trains of superior class, is, nevertheless, relieved of the necessity of guessing whether he has time to make a certain passing point or of asking of the despatcher permission to do so. There is, therefore, a simplification of the work of despatching, and the conductor has only to push his train along until warned by a signal against him of the necessity of making for a siding."

The American Railway Association, by the adoption in October, 1903, of Rules D-251 to D-254, officially recognized train operation by signal indication on double track. The title of the rules is:

"Governing the movement of trains with the current of traffic on double track by means of block signals."

In April, 1904, Rules D-261 to D-264 were added for the movement of trains *against* the current of traffic on double track by means of block signals.

Train Operation by Signal Indication on the Burlington Road

The Chicago, Burlington & Quincy Railroad, as early as 1900, began operating trains on double-track between Chicago and Burlington "with the current of traffic by block signals" and without written train orders. The rules were few and simple. After several years' trial the net results were summed up as follows:

"A large saving in the time of getting trains over the road, due to the absence of any necessity for waiting for a train of superior class which may or may not be on time; a simplification in train despatching, owing to the lack of a necessity on the part of the conductor to state that he has time to make one station farther on and to secure the despatcher's order to proceed; and a measure of safety due to getting rid of the mathematical and chronological computation above referred to.

"It was formerly required on the Burlington that freight trains should keep out of the time of the fast mail by an interval of 10 minutes; of the time of an ordinary passenger train by an interval of five minutes. Of this responsibility the conductor of the freight is now relieved. On a busy section, as between Chicago and Mendota (83 miles), it is estimated that there is a saving of one-third in delays to trains."

The late F. C. Rice, general inspector of transportation of the Chicago, Burlington & Quincy, the man mainly respons the introduction of this method of trains, said in 1911: "Our scheme ning trains on double-track by bl nals has fulfilled our most sanguine tations. It has saved our company many dollars, I am sure, over the c practices of train rules and train de ing. We have not had an accident sort resulting from the change in pra not a life lost nor a person injured."

Economic Value of Tra Operation by Signal Indic

On *double track* it is now the gener tice to run extra trains without t ders. Many roads are also using a tive form of signal at non-inter switches for directing trains to main" or "take siding." A most step in this direction was made by t Railroad on the Susquehanna divi 1910 by the use at non-interlocked s of signals giving the three indi "hold main," "take siding," or "st

J. J. Turner[12] in his book on "Tl graph as Applied to Train Movem early as 1885, set forth the advant train operation by signal indicat *single track*. Mr. Turner quotes an by E. W. McKenna[13] on "A New Tl Train Movement," from which the ing is taken:

"Assume a blocked section of track railroad 25 miles in length a following method: The passing sidi five miles apart and arranged on eit of the main track and joining th track in front of a signal stati double track rule 'keep to the r apply in the use of these siding

[11] See "Train Operation by Signal Indicatio scription of the Erie practice. H. M. Sperry, N

[12] Now Vice-President of the Pennsylvania sy

[13] Formerly Vice-President of the Chicago, M St. Paul.

Stopping for a "31"

Picking up a "19"

Train Operation by *Written* Train Orders

junctions of the sidings with the main track should overlap,[14] that is, run by each other, so that trains from both sidings can move into the main track simultaneously.

"The four switches of the passing sidings to be controlled by the operator in the signal station are operated by the electro-hydro-pneumatic process, by which switches can be set at any distance from the point where the power is applied. This station may be on a crooked piece of line and the switches at the remote ends of the sidings not in the vision of the operator. Hence that he may know, first, the position of the switches at every movement back and forth, the switches will telegraph him their position; and second, to prevent him from throwing the switch under a moving train. The train itself by action of a track circuit will lock the switch in the position it is in when the first contact of the train closes the circuit and keeps it locked until the train has cleared the switch.[15]

"The procedure will then be as follows: In the block section there will be five blocks averaging five miles each in length. At one of the termini will be located the despatcher. Priority in rights of trains of a superior over an inferior class, as well as all questions connected with the movements, will rest absolutely in the hands of the train despatcher.

"A train approaching a signal station from either direction when one mile distant will announce itself by closing a circuit and setting an indicator. Upon this the opera-

[14] See article by L. F. Loree, "Lap Sidings on the Cleveland & Pittsburgh," *Railroad Gazette*, September 13, 1901.

[15] Outlying switches are now operated electrically by low-voltage switch machines. These machines are for operating switches located at a long distance from the station. They will operate a switch in 35 seconds on 20 volts from a primary or secondary battery.

Train Operation by Signal Operation

tor will report to the train despatcher, 'train from east.' If the train from the west is to be passed the despatcher will respond 'side track,' and the operator will signify his understanding by repeating the same word and will set the switch leading into the passing siding.

. . . . . .

"What advantages follow this? First, the elimination of the danger of accident connected with the present system. The factors that produce disaster in the handling of train orders have been discussed. They are the despatcher, the operator, the conductor and the engineer; any one of these four can produce an accident. By eliminating any one or more of these factors you make the responsibility concrete, for an individual responsibility office better than a divided one.

"Accidents have been known conductor in doubt as to a point si caboose and depends on 'Jim' in th to understand it. Jim is befoggec same question, but depends on 'Bil caboose, and the result of this di responsibility is disaster.

"Under the theory discussed, th ing is all done by one man, the r bility all rests upon one man, anc under his absolute control all th ances for carrying out the system only in a small degree to depend u intelligence and assistance of the o and trainmen.

"The next proposition is the ec accomplished by saving of delays t Upon this 25 miles of track assu 100 trains pass daily; it is not an gant calculation to assume that 10 are issued daily. A delay of four for the manipulation of each order to 400 minutes, or 6 hours and 40 m day. In this time a train movin rate of 20 miles an hour will trav miles. Multiply this by 365 day produces 47,650 train miles, whicl tainly an addition to efficient power capacity."[16]

Mr. McKenna summed up the valı method of operating a railroad as f

"Its capacity can be increased to 40 per cent, its train movemen fied and expedited, and a largely i mileage produced from its motiv with a reduction of the expense wear and tear of equipment and c tion of fuel entailed by the frequent necessary stoppages of trains, and tion thereto the safety factor la creased."

[16] The I. C. C. abstract for 1918 (Class I roa gross revenue per freight train mile of $5.33. 47,650 freight train miles will total $253,974 100-mile division the amount will be four ti $1,014,898.

Single Track Operation Without Written Train Orders

A number of isolated installations of automatic block signals on short lengths of single track are in use today for operating trains by signal indication. As yet there is no such installation in the United States extending over an entire single-track division.

With the notable improvements that have been made in automatic block signaling for single track, the day is close at hand when trains will be "safely moved on single track without train orders and with but few train rules."

The following description of the operation of a single-track road in India by signal indication and without written train orders tends to confirm the above statement:

"Until recently traffic on the East Indian Railway has been handled without any officer corresponding to the American train despatcher, dependence being placed entirely on the station masters or agents using block instruments on single-track lines. It has been found that under this system frequent unnecessary delays to freight trains resulted from the desire of the agents to avoid the necessity of explaining delays to passenger trains.

"In order to relieve this situation a centralized control system has been installed. The movement of trains is placed under the control of an officer called a train controller, who directs the station masters by telephone as to which train may be held and which sent forward. The system differs only slightly from that in use on many double-track lines in England, where controllers or despatchers direct block operators as to the movements of trains. On the Indian railways the station masters direct the signalmen as to the throwing of switches and setting of signals.

"On the single-track line between Allahabad and Tundla, a distance of 262.5 miles, traffic consists of 21 trains each way in 24 hours, freight trains having a length of about 1,500 ft., with a possible load of 850 tons, and the passenger trains consisting in some cases of 12 coaches.

"This section is divided into four control districts, ranging in length from 57 miles to 86 miles, each in charge of a controller throughout the 24 hours, these men working in three shifts of eight hours each. In place of the train sheet in use by American despatchers, these Indian railway controllers make use of a plug board[17] and a graphic sheet or chart. When a train enters the section the controller takes a plug from the board and inserts it in a socket on the diagram corresponding to the terminal station. As it progresses from station to station its arrival and departure are reported by telephone to the controller, who shifts the plug correspondingly. Each plug is marked with the number of the train it represents, and its color indicates the class of the train. A station is not permitted to accept or despatch a train without orders of the controller, but ordinary single-track block operation remains in force. When a train is to be side-tracked the controller instructs the station as to which siding is to be used, and as long as the train remains on that siding its plug on the controller's board is left at that point.

"The permanent record of the movement of trains is made on a chart or

[17] J. J. Turner, in "The Telegraph as Applied to Train Movement" (1885), describes the use of a plug board in train despatching on a busy piece of single track railroad. E. W. McKenna, in 1882, devised this board and put it into use. Mr. McKenna was at that time superintendent of the Jeffersonville, Madison & Indianapolis, now a part of the Pittsburgh, Cincinnati, Chicago & St. Louis. The plug board is a crude track model.

Train Controller's Office, East Indian Railway, Allahabad
Graphic Train Sheet and "Plugboard" in Use

printed form, showing the list of stations in a column at the left, and with vertical rulings representing five-minute intervals for a period of eight hours, and a horizontal line opposite each station.[18] Different colored pencils are used for different classes of trains with which lines are drawn across this diagram, the intersections of these lines with the horizontal lines indicating the time at which each train passed the given stations. As each chart represents eight hours' work, the three charts each day form a complete record for the district superintendent.

"The installation of this system has effected important operating economies. The number of trains operated has in-

[18] See article by L. C. Fritch (now Vice-President of the Chicago, Rock Island & Pacific Railroad), "Train Despatcher's Graphic Chart," used on the Ohio & Mississippi Railway in 1891.—*Engineering News*, September 5, 1891.

creased 10 per cent, as indicated by th monthly summaries, the increase in th number of through freight trains for thes periods being 15 to 35 per cent. In spite o this increased number of trains, the aver age time on the road was decreased 10 t 15 per cent."[19]

The important economies obtained o the East Indian Railway constitute a mos favorable showing for single-track opera tion by signal indication, or operatio without *written* train orders.

Another record of single-track operatio by signal indication—a very remarkabl one and not to be lost sight of—was th operation by the Jeffersonville, Madison & Indianapolis in 1882 of 225 trains a da over the Louisville bridge and adjacen tracks entirely by signals without the us

[19] See *Railway Signal Engineer*, July, 1917.

of written train orders. This handling of a heavy traffic entirely by signals when the science of signaling had not reached its present high development was a most notable performance.

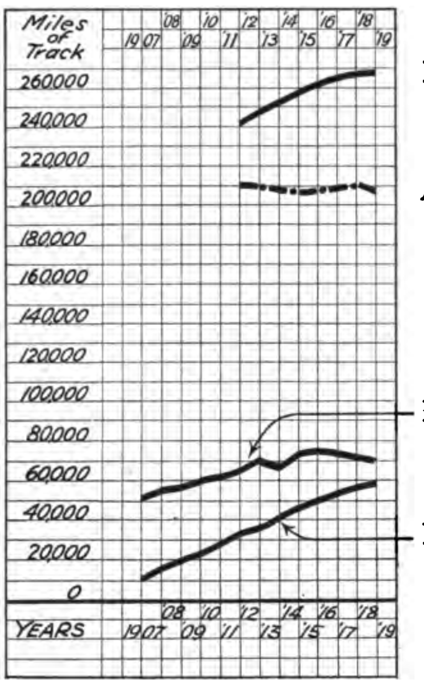
With the present development of the science of signaling, the equipment of a single-track division of a railroad with automatic block signals, interlocking signals and telephone train despatching for directing the movements of trains by signal indication without the use of written train orders, is in every detail simple and feasible, and can be carried out under arrangements which have the approval of the most conservative railroad authorities.

A single-track railroad thus equipped will fully meet the requirements of the block signal system described in a hand book, "Train Operation," written by William Nichols, for 10 years chairman of the board of examiners, Southern Pacific Company.

Mr. Nichols describes this block system as follows:

"With a proper block system, with signals to govern train movements in and out of sidings, trains may be safely moved on single track without train orders and with but few train rules."

Progress in the Installation of Block Signals



Miles of Main Track Class I Roads
268,681 miles Jan. 1, 1919

Miles of Main Track Not Yet Equipped With Automatic Block Signals
209,223 miles Jan. 1, 1919

Miles of Manual Block Signals
69,830 miles Jan. 1, 1919

Miles of Automatic Block Signals
59,458 miles Jan. 1, 1919

The Progress Chart was prepared from statistics of the Interstate Commerce Commission

The progress chart above visualizes the progress made in equipping the railroads of the United States with block signals. The relative progress of the two block systems, measured in miles of track, is shown in detail in the following table of the 12-year period from 1907 to 1919:

The average annual increase of 3,893 miles of track of the automatic block system is 2½ times the average annual in-

Block Signal Progress 1907 to 1919

	1907 January 1	1919 January 1	Total Increase	Aver. An Increa
	Miles of Track		Miles of Track	
Manual block system	51,685	69,830	18,145	1,51
Automatic block system	12,745	59,458	46,713	3,89

Main Track Mileage vs. Block System Mileage

	1912 January 1	1919 January 1	Total Increase	Aver. An Increa
	Miles of Track		Miles of Track	
Main track Class I roads	246,747*	268,681	21,944	3,13
Manual block system	66,072	69,830	3,758	53
Automatic block system	33,425	59,458	26,033	3,71
Main track not equipped with automatic block system	213,322	209,223	4,099†	58

* Estimated as of January 1, 1912. † Decrease

crease of the manual block. In other words, for every mile of manual block installed, 2½ miles of automatic block was installed. From the standpoint of comparative progress this rate of increase of the automatic block over the manual block might be regarded as satisfactory. Yet it is not satisfactory when compared with the average annual increase of main-track mileage.

On January 1, 1919, the total miles of track equipped with automatic block signals was 59,458. Deduct this from the total of 268,803 miles of main track on the same date and there remains a balance of 209,223 miles of main track Class I roads[20] *not* equipped with automatic block signals.

Table 2 shows the relative progress of main-track mileage and block-system mileage for seven years, 1912 to 1919.

[20] Class I roads are those having each an annual operating revenue above $1,000,000.

The significant point in this table is the average increase for automatic b system, 3,719 miles, is only 586 ı in excess of the average annual incı for main-track Class I roads (3 miles). Therefore, unless there marked increase in the annual mileag the automatic block system, the n track mileage and automatic block mil will continue to run nearly parallel each other. It is acknowledged univer that the automatic block system is ideal system of signaling, for econom track facilities and promoting prc movement of trains, and also the best ventive of collisions. And its usefulne not confined to lines of dense traffic. in use on some lines where the volun traffic is not to be classed as heavy; bı value is evident, and is appreciate definitely on such lines as on those w are more constantly busy.

Any railroad which aims to give the public the best possible service has a duty not only to keep up with "the state of the art" according to the very easy standards in this respect which are laid down by the courts, but to establish the ***highest possible standards***. Establishing high standards at large expense may sometimes seem, because of the indifference, ignorance or hostility of legislatures and municipal and other authorities, to be a thankless task, and it is not to be denied that some of the difficulties are hard to remove. But there is still to be kept in mind the broad view, looking well to the future, that high standards of safety and efficiency do afford the most satisfactory ultimate results.

Transportation is the carriage of persons and commodities from one place to another. Transportation means movement. Movement, to be efficient, must be directed. The means for directing movement must be efficient. Automatic block signals constitute the ideal means for the direction of movement—that is, for the ***direction of train operation***.

Operating Efficiency

The efforts that have been made to increase operating efficiency have largely been in the direction of:

1 Increasing the tractive power of the locomotive

2 Increasing car capacity

3 Increasing track facilities by the addition of second, third and fourth main tracks, longer passing sidings and larger yards and terminals

4 By the electrification of steam-operated roads

These improvements, which require large expenditures, may fail to show an adequate return if the means for directing train operation does not keep trains moving.

Appendix

Principles of Train Despatching

The principles of train despatching were clearly set forth years ago by J. J. Turner in his book on "The Telegraph as Applied to Train Movement," in the following terse paragraphs:

"*First*. That to prevent conflicting instructions and to insure safety, no more than one man can despatch trains on the same track at the same time."—Complied with by a rule to that effect.

"*Second*. That the despatcher be kept fully advised of all delays, present or prospective, and the position of every train on the road."—Complied with by reports from stations and terminals.

"*Third*. That orders must be so clearly expressed as to render a misunderstanding of their meaning impossible."—Complied with by the use of rules and forms of the Standard Code.

"*Fourth*. That the despatcher must know that they are in the hands of some reliable party for delivery."—Complied with by the acknowledgment of the operator giving his initials and office call.

"*Fifth*. That it is as near certain as anything human can be, that the party who is to deliver them will stop the train to which they are addressed."—Complied with at each train order office, by the use of a fixed signal which shall indicate "stop" when trains are to stop for train orders.

"*Sixth*. That when delivered to trainmen, they read just as they did when sent by the despatcher."—Complied with the receiving operator, who repeats completed order to the despatchei verification.

"*Seventh*. That the instructions give both trains are identical."—Comj with by the use of the duplicate c system.

"*Eighth*. That the train whose right: extended must not be moved agains train whose rights are curtailed, wit notice to the latter."—Complied wit sending the order first to the t whose right is restricted before com ing the order to the train whose rig extended.

"*Ninth*. That men who are to act t orders, acknowledge their receipt Complied with by rules relating to ' and "19" orders.

"*Tenth*. That men using them know they are doing so with the full knowl and authority of the despatcher Complied with by the response " rect" from the train despatcher.

"*Eleventh*. That trains running ag other trains under special orders mu able to recognize each other."—(plied with by giving the number o engine of every train mentioned ir order, or by train number indicator

"*Twelfth*. That a complete record be of each transaction."—Complied by use of the despatcher's order bo

Freight Train Costs are Decreased by Increasing Average Speed[21]

TIME saved by Automatic Block Signals as mentioned on page 12, shows an annual net earning on cost of the block signals of 23%.

Increasing the average speed of freight trains from 11 miles per hour to 12.5 miles per hour by eliminating preventable delays by the use of automatic block signals on a 100-mile division operating 16 freight trains daily shows a total saving of $86,546 per year.

Eliminate preventable delays and the average speed of freight trains can be increased without increasing maximum speed. Eliminating delay is saving time. To measure the money value of a train hour saved, the average cost per freight train *hour* must be computed. The U. S. R. A. statistics on summaries O. S. 1 and O. S. 6, May to October, 1919, give an average *speed* for freight trains of 10.6 M. P. H. and a direct cost of $1.5562 per freight train mile. Speed multiplied by cost equals $16.50 the average cost per freight train *hour* at 10.6 M. P. H. The details of this cost are:

(*a*) Locomotive repairs; engine house expense; locomotive and train supplies	$6.52
(*b*) Locomotive fuel	4.78
(*c*) Enginemen's and trainmen's wages	5.20
Freight train cost per hour at 10.6 M. P. H.	$16.50

The saving per hour when delays are eliminated is in:

(*a*) Locomotive repairs, etc. not saved, as this item is on a mileage basis.	
(*b*) Locomotive fuel; when the locomotive is standing by, the fuel consumption is about one-third of the running consumption or one-third of $4.78 is saved	$1.60
(*c*) Enginemen's and trainmen's wages 100% (in this case) saved	5.20
Saving per hour by eliminating delay	**$6.80**

The financial result (shown on the opposite page) is based on the above figures and shows the actual cost of freight train service at 10.6 M. P. H. (*a*) and the estimated reduction in cost if average speed is increased to 11 (*b*) or 12.5 M. P. H. (*c*).

[21] Reprinted from Bulletin No. 2

How Costs are Decreased by Decreasing Average Speed

Saving in Freight Train Operating Cost

	(a)	(b)	(c)
Miles per hour	10.6	11.0	12.5
Time between terminals—hours	9.43	9.1	8.0
COST:			
Per freight train mile . . .	$1.5562	$1.5335	$1.45[illegible]
Per 100 freight train miles per freight train per day .	155.62	153.35*	145.8[illegible]
Per 16 freight trains per day	$2,489.92	2,453.60	$2,333.9[illegible]

Cost per year for 16 freight trains per day:

At 11 M. P. H. ($2453.60 x 365)	$895,564.[illegible]
At 12.5 M. P. H. ($2333.92 x 365)	851,881.[illegible]
Saving per year in freight train operating cost by increasing speed to 12.5 miles per hour	$43,683.[illegible]

Saving in Equipment

A saving of only one hour per freight train per day will save the equipment required to produce 16 freight train hours per day. This equipment is 3.49 locomotives and 278 freight cars. At $82,000 per locomotive and $2,850 per car this equipment would cost . .	$1,078,480.00
As against a cost for block signals of	380,000.00
The difference in cost of equipment is	$698,480.00

Saving in Interest and Depreciation

Saving per year, in interest at 5% on cost of equipment saved is ($698,480 x 5%)	34,924[illegible]
If life of locomotives, cars and block signals be assumed to be twenty years and the salvage 20% there would be a *saving in annual depreciation* on difference in cost of equipment of ($698,480 x 4%) .	27,939[illegible]

Gross Saving

Saving per year in freight train operating cost, interest and depreciation	$106,546

Net Saving

Annual cost of operating and maintaining automatic block signals on the basis of $200 per mile	20,000
Annual net saving due to increasing average speed of 16 freight trains over 100 miles of line, to 12.5 miles per hour, through use of Automatic Block Signals	$86,54[illegible]

Net Earning 23%

Which equals an annual net earning on cost of automatic block signal installation of	2[illegible]
To say nothing of other savings and greatly increased	SAF[illegible]

*$153.35 = 155.62 − ($6.80 × .33 hrs.) = 155.62 − 2.27 = $153.35.
†$145.87 = 153.35 − ($6.80 × 1.1 hrs.) = 153.35 − .748 = $145.87.

THIS BULLETIN is number three* of a series to be issued from time to time for the purpose of placing in convenient form information in relation to "Train Operation by Signal Indication."

UNION SWITCH & SIGNAL COMPANY
Swissvale, Pennsylvania

GENERAL RAILWAY SIGNAL COMPANY
Rochester, New York

FEDERAL SIGNAL COMPANY
Albany, New York

HALL SWITCH & SIGNAL COMPANY
Garwood, New Jersey

"Signals keep trains moving"

*No. 1. Train Operation by Signal Indication on Susquehanna Division, Erie Railroad

No. 2. Train Operation by Signal Indication
What Time Saved by Signal Means in Equipment
What Does It Cost to Stop a Tonnage Train?